Manual of Instructions

MODEL 459B

Crystal Impedance Meter

RFL Industries, Inc.
Boonton, New Jersey, U.S.A.

Manual of Instructions

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Crystal Impedance Meter

1-15 Mc

Crystal Impedance Meter

(TS-330/TSM Improved Type)

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RFL Industries, Inc.

Boonton, New Jersey, U. S. A.

Warranty

The Model 459B 1-15 Mc Crystal Impedance Meter carries a warranty of 12 months from date of delivery for replacement of any part which fails during normal operation or service. A deficient part should be returned to the factory, shipping charges prepaid, for replacement f. o. b. Boonton, New Jersey.

RFL Industries, Inc.

Boonton, New Jersey, U. S. A.

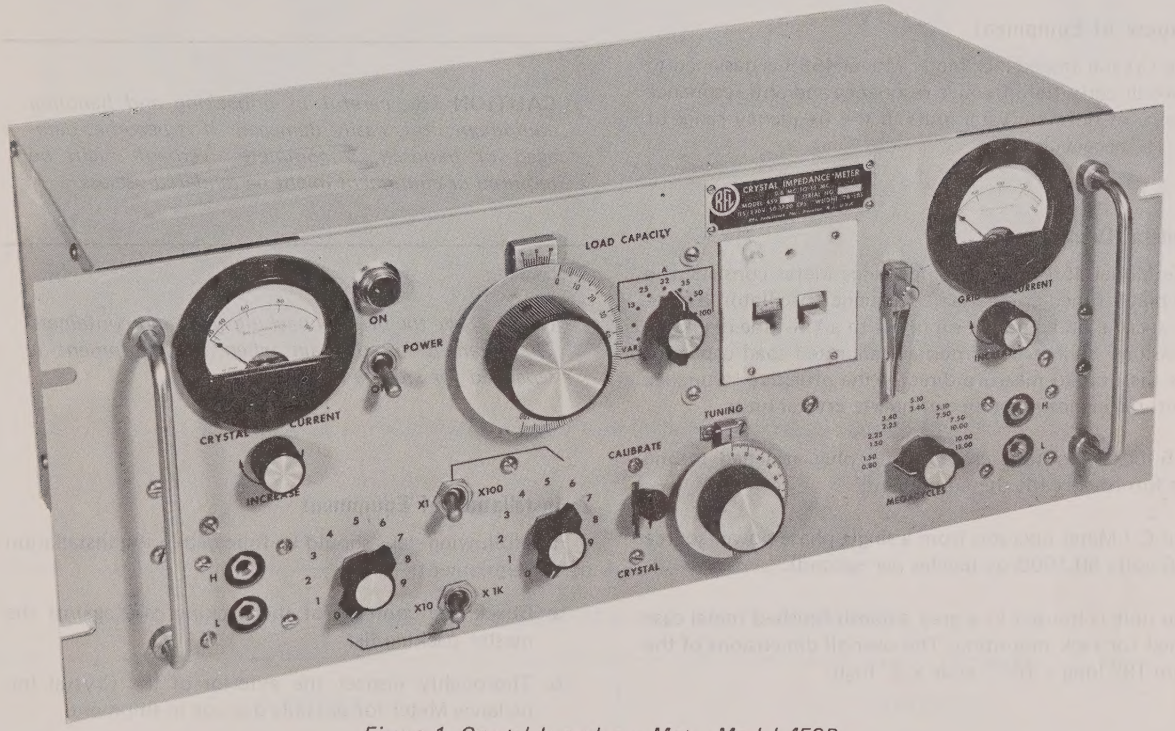


Figure 1. Crystal Impedance Meter Model 459B.

GENERAL DESCRIPTION

1. Purpose of Handbook

The purpose of this handbook is to provide operating and servicing personnel with the necessary information concerning the installation, operation, and maintenance of the Crystal Impedance Meter Model 459B.

2. Purpose of Equipment

The Crystal Impedance Meter Model 459B is designed to measure directly the effective resonance and anti-resonance resistance of quartz crystal units in the frequency range of 0.8 – 15 megacycles.

3. General Description

The Model 459B Crystal Impedance Meter consists of a tuned-plate, tuned-grid variable frequency oscillator, a resistance decade, and a power supply with a VR-tube-regulated plate-voltage source. An internal calibrated load capacitor allows the unit to measure directly the effective resonance and anti-resonance resistance of quartz crystal units.

A 5-foot r-f output cable with a plug attached to one end is furnished with the equipment.

The C I Meter operates from a single-phase power source of 115 volts 50-1000cps (cycles per second).

The unit is housed in a grey smooth-finished metal case designed for rack mounting. The over-all dimensions of the unit are 19" long x 10½" wide x 7" high.

4. Technical Characteristics

The characteristics of the Crystal Impedance Meter Model 459B are as follows:

Frequency Ranges: Seven ranges: 0.8–1.50 mc, 1.50–2.25 mc, 2.25–3.40 mc, 3.40–5.10 mc, 5.10–7.50 mc, 7.50–10.00 mc, 10.00–15.00 mc. Ranges overlap.

Resistance Calibration Ranges: By use of a toggle switch and two selector switches, the following resistance ranges are obtainable: 0 ohms to 99 ohms in 1-ohm steps, 0 ohms to 990 ohms in 10-ohm steps, 0 ohms to 9,900 in 100-ohm steps.

Load Capacitance: 13, 25, 32, 35, 50, and 100pF precise fixed load capacitors accurate to ±.1pF. Also a 17 to 100pF variable capacitor with a 100 division dial calibrated to ±0.5pF.

Number of Tubes: 4
Oscillator – 6V6GT
Rectifier – 5Y3GT
Voltage Regulator – OC3
Voltage Regulator – OC3

Required Power Source: 115/230 volt a-c, 50 to 1,000cps.

INSTALLATION AND ADJUSTMENT

1. Unpacking the Equipment

Cut the metal bands. Open the cartons that protect the equipment; or, if heavy wrapping paper has been used, remove it carefully and take out the components. Check the contents of the packing case against the master packing slip.

CAUTION: *Be careful in unpacking and handling equipment; it is easily damaged. If it becomes damaged or exposed, a complete overhaul might be required or equipment might be rendered useless.*

NOTE: *Save the original packing cases and containers. They can be used again when the equipment is repacked for storage or shipment.*

2. Installation of Equipment

The following steps should be followed in the installation of the equipment:

a. Check the contents of the packing case against the master packing list.

b. Thoroughly inspect the exterior of the Crystal Impedance Meter for possible damage in shipment.

c. Loosen the nine binding head screws on the sides and back of the unit and remove the metal dust cover. Also remove the bottom cover plate.

d. Make sure no vacuum tubes are broken and that they are properly seated in their sockets.

e. Inspect the wiring to make certain that the leads are securely fastened to points of contact.

f. Inspect the subassembly parts such as terminal strips to make certain they are securely fastened in place.

g. Remove the cap from the fuseholder located on the back of the chassis (Figure 7) and see that the fuse (1 ampere) has been installed.

h. Replace the dust cover and bottom plate.

3. Controls and Instruments

a. General – Haphazard operation or improper setting of the controls can cause damage to electronic equipment. For this reason it is important to know the function of every control. The actual operation of the equipment is discussed on page 7.

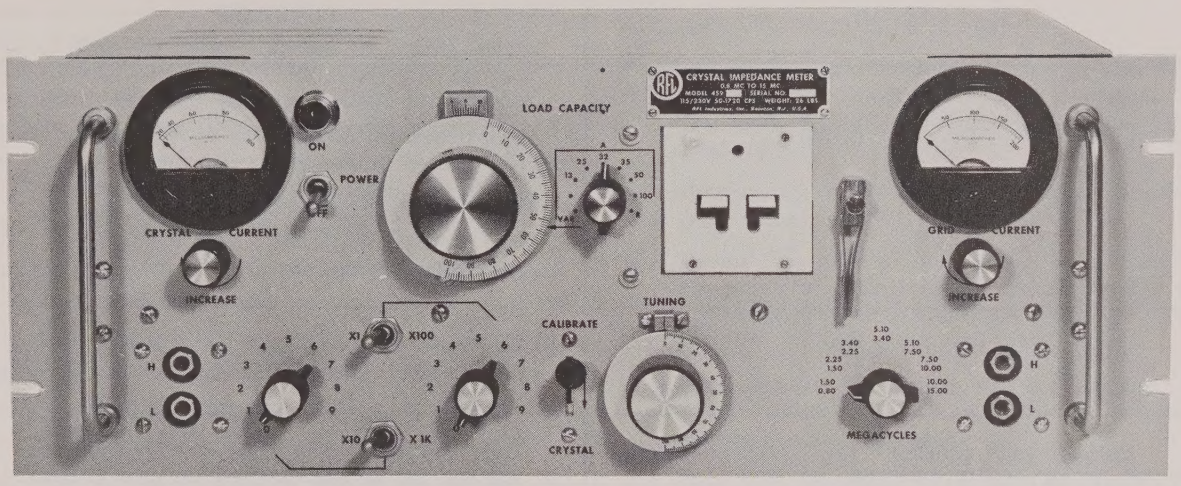


Figure 2. Front Panel View of Crystal Impedance Meter Model 459B.

TABLE 2-1 CONTROLS AND THEIR FUNCTIONS	
CONTROL	**FUNCTION**
ON-OFF switch (S108).	Connects the equipment to power source.
CALIBRATE-CRYSTAL switch (S107).	The CRYSTAL position is used to switch the crystal unit into the oscillator circuit. Move the switch to CALIBRATE position after the circuit initially is adjusted to the test crystal to substitute the equivalent resistance for the unit being tested.
MEGACYCLES switch (S105).	The oscillator may be tuned to any frequency between 1 mc and 15 mc by means of the range selector switch and the oscillator tuning control.
TUNING control (C101).	The TUNING control is used in connection with the band selector switch noted above for tuning the oscillator to the desired frequency.
Crystal socket.	A two-pin crystal socket with a center-to-center pin in spacing of .5 inch to 1.25 inch.

TABLE 2-1 CONTROLS AND THEIR FUNCTIONS (Cont'd)	
CONTROL	**FUNCTION**
LOAD CAPACITY switch (S106).	Switch (marked A-R) is used to select either resonance or anti-resonance operation of the crystal unit under test. In the A positions, the crystal unit operates at anti-resonance with the load capacitance selected. In the R position, the crystal unit operates at resonance.
LOAD CAPACITY dial (C102).	The vernier control is used for setting the variable load capacitance in anti-resonance operation.
Decade resistor switches (S101, S102) and range toggle switches (S103, S104).	These controls consist of two selector switches and two toggle switches. They are used to select a resistance equivalent to the crystal unit resistance.
CRYSTAL CURRENT control (R142).	By means of this control, the amount of current passing through the crystal unit under test can be varied.
GRID CURRENT meter (M101).	The GRID CURRENT meter is a d-c microammeter used to indicate a convenient proportion of the total rectified grid current.
CRYSTAL CURRENT meter (M102).	The CRYSTAL CURRENT meter is an r-f thermocouple type which measures the magnitude of the r-f crystal unit current.
GRID CURRENT control (R141).	This control is used to vary the setting of a shunt resistor across the GRID CURRENT meter, so that convenient readings may be obtained.
Vacuum-tube voltmeter jacks H and L (J101, J102) (J103, J104).	These jacks provide connections to voltmeters for measurement of voltage across the crystal unit.
Light indicator (I-101).	Pilot lamp; indicates the presence of line voltage.
Coaxial connector receptacle (J105).	Used to connect the r-f cable assembly to the meter. Supplies r-f output to frequency measuring equipment.

OPERATION

1. Measurement of Resonance Resistance

CAUTION: *To prevent damage to meter, adjust CRYSTAL CURRENT and GRID CURRENT controls to their minimum positions (maximum counterclockwise position) before turning instrument on.*

---

a. Insert the a-c cable assembly (W102) plug into a 115 volt, 50 to 1,000cps a-c source.

b. Switch the ON/OFF switch to ON. Allow 15 minutes for warm-up.

c. Switch the CALIBRATE-CRYSTAL switch to CRYSTAL position.

d. Set the MEGACYCLES switch to the proper frequency range.

e. Turn LOAD CAPACITY switch to position R.

f. Insert the crystal unit in the crystal socket.

g. Increase the GRID CURRENT control slightly in a clockwise direction.

h. Adjust the TUNING control for maximum GRID CURRENT meter reading. It may be necessary to increase the GRID CURRENT and CRYSTAL CURRENT controls in order to obtain a convenient GRID CURRENT meter reading. The crystal unit current, as indicated on CRYSTAL CURRENT meter M102, should be held as small as possible with the GRID CURRENT meter at maximum.

CAUTION: *Do not increase the CRYSTAL CURRENT control more than is necessary, as damage to crystal unit and equipment may result.*

---

i. Make an approximate measurement of the crystal frequency by connecting cable assembly W101 from J105 to a radio receiver with the beat-frequency oscillator turned on.

j. Set the decade resistors to the maximum specified resistance for the particular crystal under test.

k. Switch the CALIBRATE-CRYSTAL switch to CALIBRATE-CRYSTAL switch to CALIBRATE position. If the GRID CURRENT meter goes off-scale, immediately switch enough resistance (by means of the decade resistors) into the circuit to bring the GRID CURRENT meter reading back to the value obtained in the CRYSTAL position.

l. Adjust the TUNING control so that the signal is at zero-beat with the frequency measured in paragraph i.

m. Move the CALIBRATE-CRYSTAL switch to CRYSTAL position.

n. Adjust the GRID CURRENT control to obtain any convenient value of meter reading. This adjustment should remain fixed throughout the remainder of the test.

o. Switch to CALIBRATE position.

p. Adjust the decade resistors to obtain the same value of GRID CURRENT meter reading as when the CALIBRATE-CRYSTAL switch was in the CRYSTAL position.

q. Readjust the TUNING control to obtain the same frequency as in the CRYSTAL position.

r. Repeat steps given in paragraphs p. and q. above, if necessary, to obtain identical grid current and frequency values in both CALIBRATE and CRYSTAL positions.

s. Read the value of resistance from the settings of the decade resistors. This is the effective resonance resistance of the crystal unit.

t. Move CALIBRATE-CRYSTAL switch to CRYSTAL position. Make an accurate measurement of the operating frequency by connecting cable assembly W101 to an appropriate frequency-measuring instrument such as the following: Frequency Meter FR-4, Frequency Measuring Assembly CY-93/FSM-1, or Frequency Meter SCR-211; selection of the meter to be used depends on the intended use and the accuracy desired.

2. Measurement of Anti-Resonance Resistance

CAUTION: *To prevent damage to the meter, adjust CRYSTAL CURRENT and GRID CURRENT meter controls to their minimum positions (maximum counterclockwise position) before turning the instrument on.*

---

a. Insert the a-c cable assembly (W102) plug into a 115 volt, a-c source.

b. Switch the ON/OFF switch to ON. Allow 15 minutes for warm-up.

c. Switch the CALIBRATE-CRYSTAL switch to CRYSTAL position.

d. Set the MEGACYCLES switch to the proper frequency range.

e. Turn LOAD CAPACITY switch to the value of load capacity desired or to VAR, variable load, if the value is non-standard.

f. If the variable load capacity is to be used, adjust the LOAD CAPACITY dial to the proper setting. If the fixed capacitors are used, set the LOAD CAPACITY dial to 0 for greatest accuracy due to a maximum of .05pF interaction between capacitors.

g. Insert the crystal unit in the crystal socket.

h. Increase the GRID CURRENT control slightly in a clockwise direction.

i. Adjust the TUNING control for maximum GRID CURRENT meter reading. It may be necessary to increase the GRID CURRENT and CRYSTAL CURRENT controls in order to obtain a convenient GRID CURRENT meter reading. The crystal current as indicated by CRYSTAL CURRENT meter M102 should be held as low as possible with the GRID CURRENT meter at maximum sensitivity.

CAUTION: *Do not increase the CRYSTAL CURRENT control more than is necessary, as damage to crystal unit and equipment may result.*

---

j. Make an approximate measurement of crystal frequency. This may be done by connecting cable assembly W101 from J105 to a radio receiver with the beat-frequency oscillator turned on.

k. Set the decade resistors to the maximum specified resistance for the particular crystal under test.

l. Switch the CALIBRATE-CRYSTAL switch to CALIBRATE position. If the GRID CURRENT meter goes off-scale, immediately switch enough resistance (by means of the decade resistors) into the circuit to bring the GRID CURRENT meter reading back to the setting obtained in the CRYSTAL position.

m. Adjust the TUNING control so that the signal is at zero-beat with the frequency measured in paragraph j. above.

n. Switch the CALIBRATE-CRYSTAL switch to CRYSTAL position.

o. Adjust the GRID CURRENT control to obtain a convenient value of meter reading. This adjustment should remain fixed throughout the remainder of the test.

p. Move the CALIBRATE-CRYSTAL switch to CALIBRATE position.

q. Adjust the decade resistor to obtain the same value of GRID CURRENT meter reading as when the CALIBRATE-CRYSTAL switch was in CRYSTAL position.

r. Readjust the TUNING control to the same frequency as in the CRYSTAL position.

s. Repeat steps in paragraphs q. and r. above, if necessary, to obtain identical grid current and frequency values in both the CALIBRATE and CRYSTAL positions.

t. Read the value of resistance from the settings of the decade resistors. This is the effective anti-resonance resistance of the crystal unit.

u. Move the CALIBRATE-CRYSTAL switch to CRYSTAL position. Make an accurate measurement of operating frequency (as described in para. 1t). This value is the anti-resonance frequency.

3. Procedure For Using The C. I. Meter As A Go/No-Go Gage, Resonance Operation

a. Insert the a-c cable assembly (W102 plug into a 115 volt a-c source.

b. Switch the ON/OFF switch to ON. Allow 15 minutes for warm-up.

c. Adjust the crystal drive according to information given in the specification covering the particular crystal unit under test. Where no drive level has been established, the crystal should be maintained at as low a level as possible. To accomplish this, advance the GRID CURRENT control to its extreme clockwise position, and then advance the CRYSTAL CURRENT control to that position which will give an adequate current reading.

d. Turn LOAD CAPACITY switch to R position.

e. Set the MEGACYCLES switch to the proper frequency range.

f. Set CALIBRATE-CRYSTAL switch to CRYSTAL position.

g. Insert the crystal unit in the crystal socket.

h. Adjust the TUNING control for maximum GRID CURRENT meter reading. It may be necessary to adjust the GRID CURRENT control so as to obtain a convenient GRID CURRENT meter reading.

CAUTION: *Do not disturb the CRYSTAL CURRENT control as this should remain fixed (para. c. above) for the remainder of the test.*

---

i. Make an approximate measurement of the crystal frequency by connecting cable assembly W101 from J105 to a radio receiver with the beat-frequency oscillator turned on.

j. Set the CALIBRATE-CRYSTAL switch to CALIBRATE position.

k. Adjust decade resistors to the value which corresponds to the maximum permissible resistance for the frequency desired as indicated in the applicable crystal unit specification.

l. Adjust the TUNING control so that the signal is at or near zero-beat with the frequency measured in paragraph 3i.

m. Adjust the GRID CURRENT control to obtain any convenient value of meter reading. This adjustment should remain fixed throughout the remainder of the test.

n. Note the GRID CURRENT value. This value is the passing activity level.

o. Set CALIBRATE-CRYSTAL switch to CRYSTAL position.

p. Crystals exhibiting a greater GRID CURRENT meter reading than obtained in paragraph n. above, pass the activity requirements; those showing less, fail.

q. The procedure outlined must be repeated each time the crystal unit frequency is changed.

4. Procedure For Using The C. I. Meter As A Go/No-Go Gage, Anti-Resonance Operation

a. Insert the a-c cable assembly (W102) plug into a 115 volt a-c source.

b. Switch the ON/OFF switch to ON. Allow 15 minutes for warm-up.

c. Adjust the crystal drive according to information given in the specification covering the particular crystal unit under test. Where no drive level has been established, the crystal should be maintained at as low a level as possible. To accomplish this, advance the GRID CURRENT control to its extreme clockwise position, and then advance the CRYSTAL CURRENT control to that position which will give a convenient GRID CURRENT meter reading.

d. If VAR, variable load, is used, turn LOAD CAPACITY switch to VAR position and LOAD CAPACITY dial to desired load capacitance.

e. Set the MEGACYCLES switch to the proper frequency range.

f. Set the CALIBRATE-CRYSTAL switch to the CRYSTAL position.

g. Insert the crystal unit in the crystal socket.

h. Adjust the TUNING control for maximum GRID CURRENT meter reading. It may be necessary to adjust the GRID CURRENT control in order to obtain a convenient GRID CURRENT reading.

CAUTION: *Do not disturb the CRYSTAL CURRENT control as this should remain fixed (para. c. above) for the remainder of the test.*

---

i. Make an approximate measurement of the crystal frequency. This may be done by connecting cable assembly W101 from J105 to a radio receiver with the beat-frequency oscillator turned on.

j. Set the CALIBRATE-CRYSTAL switch to CALIBRATE position.

k. Adjust the decade resistors to the value which corresponds to the maximum permissible resistance for the frequency desired as indicated in the applicable crystal unit specification.

l. Adjust the TUNING control so that the signal is at or near zero-beat with the frequency measured in paragraph i. above.

m. Adjust the GRID CURRENT control to obtain any convenient value of meter reading. This adjustment should remain fixed throughout the remainder of the test.

n. Note the GRID CURRENT value. This value is the passing activity level.

o. Set CALIBRATE-CRYSTAL switch to CRYSTAL position.

p. Crystals exhibiting a greater GRID CURRENT meter reading than obtained in paragraph n. above, pass the activity requirements; those showing less, fail.

q. The procedure outlined must be repeated each time the crystal unit frequency is changed.

5. Operating Instructions For Using The C. I. Meter With Crystal Test Block At Anti-Resonance

If it is desired to temperature-cycle individual crystals operating at anti-resonance with a given value of load capacitance, use a test block, or equivalent, containing a padding capacitor mounted in series, with one of the crystal leads. Proceed as follows:

a. Find the exact frequency of crystal unit under test, as outlined in the anti-resonance test procedure in paragraph 2.

b. Remove the crystal unit from the socket and insert in the test block. Insert the test block in the crystal socket.

c. Turn LOAD CAPACITY switch to position R.

d. Adjust the trimmer capacitor in the crystal test block until the frequency of the crystal is precisely the same as the frequency found in paragraph a. above. The test block is now ready for operation.

6. Operating Instructions For Using The C. I. Meter With Crystal Test Block At Resonance

If it is desired to temperature-cycle individual crystals operating at resonance, use a temperature test block without a series padding capacitor. Proceed as follows:

a. Insert the crystal test block in the crystal socket.

b. Turn LOAD CAPACITY switch to position R.

c. Insert the crystal unit in the test block. The block is now ready for use.

THEORY OF OPERATION

1. Crystal Parameters, General

a. **Piezoelectric Effect** — When an electrical stress is applied to a cut quartz crystal in the direction of one of the major axis, a mechanical stress is produced at right angles to this axis. Conversely, a mechanical stress along a major axis will cause electrical charges to appear on the faces of the crystal perpendicular to the stress axis. The polarity of the electrical stress and the direction of the corresponding mechanical force are directly related; a reversal in one causes a reversal in the other. This relationship between electrical stress and mechanical force is termed the piezoelectric effect, and provides a means of relating mechanical vibrations to electrical circuits.

b. **Resonance** — An alternating voltage applied a quartz crystal will cause the crystal to vibrate; if the frequency of the applied alternating voltage approximates a frequency at which mechanical resonance can exist in the crystal, the amplitude of the vibrations will be very large. Any crystal has several such resonant frequencies that depend on the crystal dimensions, the type of oscillation involved, and the orientation of the plate cut from the natural crystal.

c. **Properties of Piezoelectric Resonator** — A good piezoelectric resonator possesses the following properties: 1 low-temperature coefficient of resonant frequency, a high piezoelectric activity (performance index), and a frequency spectrum containing only one resonant frequency in the vicinity of the desired oscillation. Temperature can alter the frequency of mechanical resonance through its effects on the density, the linear dimensions, and the module of elasticity of the crystal. Since some of the elastic constants are positive and others negative, the temperature coefficient of frequency may be either positive, negative, or zero, according to the mode of oscillation, the orientation of the crystal plate and the shape of the plate. The electrical circuit associated with a vibrating crystal is shown in Figure 3. The capacity, C_O, represents the electrostatic capacity between the crystal electrodes when the crystal is in place but not vibrating; the series combination of L, C, and R represents the equivalent mass, compliance and frictional loss of the vibrating crystal, respectively. Read TM 11-2540 for more detailed information on this subject.

2. Measurement

a. **Static Capacitance, C_O** — The value of the static capacitance of the crystal unit, C_O' may be measured by any conventional capacitance measuring unit. If this measurement is made with the use of a Q meter or an r-f bridge, be careful to select a frequency of operation somewhat lower than the crystal unit frequency. Figure 3 shows a diagram of the parameters of a piezoelectric crystal.

b. **Resonance and Anti-Resonance Resistances** — The measurement of the effective resistance in ohms at resonance is outlined in the operational procedure, paragraph 1. The measurement of effective resistance in ohms at anti-resonance is outlined in the operational procedure, paragraph 2.

c. **Measurement of Motional Capacitance C_1, Inductance L_1, and Crystal Q** — The frequency of anti-resonance (f_rL) with a given load capacitor (C_L) in series with the crystal unit and the equivalent substitution resistance are first measured with the CIM. The frequency of resonance (f_r) and the equivalent substitution resistance are then measured. Measure C_O on a capacitance bridge. With this data the motional capacitance C_1, motional indictance L_1 and the crystal Q can be calculated with the following equations.

$$C_1 = \frac{2\,(C_O + C_L)\,(f_rL - f_r)}{f_r}$$

d. **Inductance L** — Use the following equation to calculate inductance, L_1, in the series arm of the crystal:

$$L_1 = \frac{1}{4\pi^2 f_s 2C_1} \qquad f_s \approx f_r$$

e. **Crystal Q** — Use the following equation to obtain the crystal Q:

$$Q = \frac{2\pi f_s L_1}{R_1}$$

f. **Crystal Drive Level** — The amount of power dissipated in the crystal unit at resonance is a measure of the motional excursions of the crystal. The power is calculated by the equation:

$$P = \frac{E^2}{R}$$

where
E is the voltage across an appropriate substitution resistor (R). (E may be obtained by subtracting the voltages at the front panel jacks J103 - J104 and J102 - J101).

R is the substitution resistor equal to the effective resonance resistance of a "series resonant" crystal unit or the effective resonant resistance of the combination of an "anti-resonant" crystal unit in series with a load capacitance (C_L).

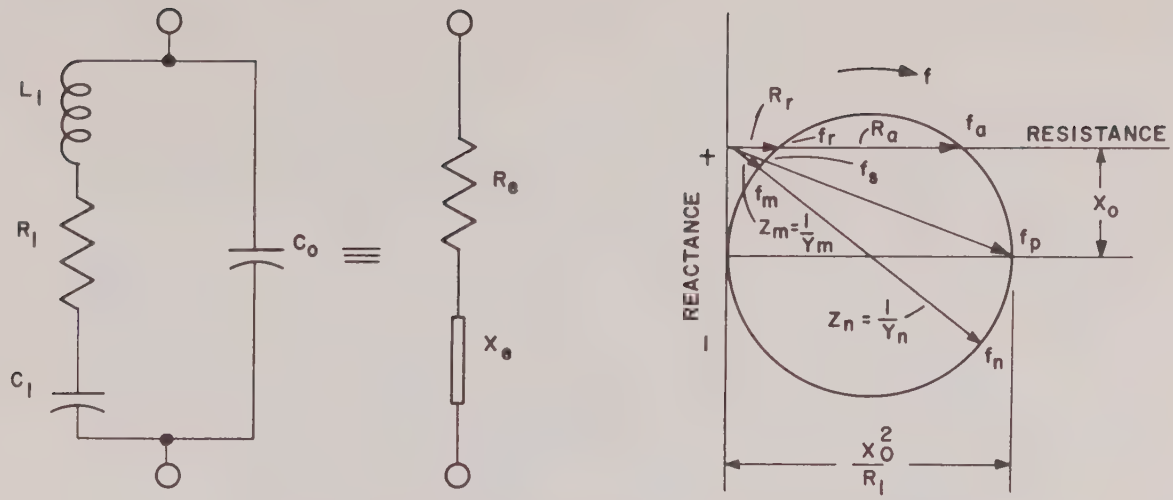


Figure 3. Equivalent Electrical Circuit Of A Piezoelectric Crystal.

C_1 = Motional Capacitance

L_1 = Motional Inductance

R_1 = Motional Resistance

C_o = Shunt (Parallel) Capacitance

$r = \frac{C_o}{C_1}$ Capacitance Ratio

f_m = Frequency at Minimum Impedance

f_s = Motional (Series) Resonance Frequency =

$$\frac{1}{2\pi\sqrt{L_1 C_1}}$$

f_r = Resonance Frequency (Reactance $X_e = 0$)

f_a = Anti-resonance Frequency (Reactance $X_e = 0$)

f_p = Parallel Resonance Frequency =

$$\frac{1}{2\pi}\sqrt{\frac{1}{L_1 C_1}\left(1+\frac{1}{r}\right)}$$

f_n = Frequency at Maximum Impedance

$Z = \frac{1}{Y} = R_e + jX_e$ = Impedance of Vibrator

Z_m = Impedance at f_m (Minimum Impedance)

Z_n = Impedance at f_n (Maximum Impedance)

R_r = Impedance at f_r, Resistive (Resonance Resistance)

R_a = Impedance at f_a, Resistive (Anti-resonance Resistance)

$Q = \frac{\omega s L1}{R_1}$ = Quality Factor

and

$M = \frac{Q}{R} = \frac{1}{\omega s C_o R_1}$ = Figure of Merit $= \frac{X_o}{R_1}$

where

$\omega = 2\pi f$; $X_o = \frac{1}{\omega s C_o}$

L_o = Inductance in Parallel with Vibrator

C_L = Load Capacitance

R_{st} = Standard Resistor

f_{mT} = Frequency of Maximum Transmission

f_{sL} = Motional Resonance Frequency of Combination of Vibrator and C_L

f_{mTL} = Frequency of Maximum Transmission of Combination of Vibrator and C_L

R_{1L} = Resulting Motional Resistance of Combination of Vibrator and C_L

f_{rL} = Resonance Frequency of Combination of Vibrator and C_L

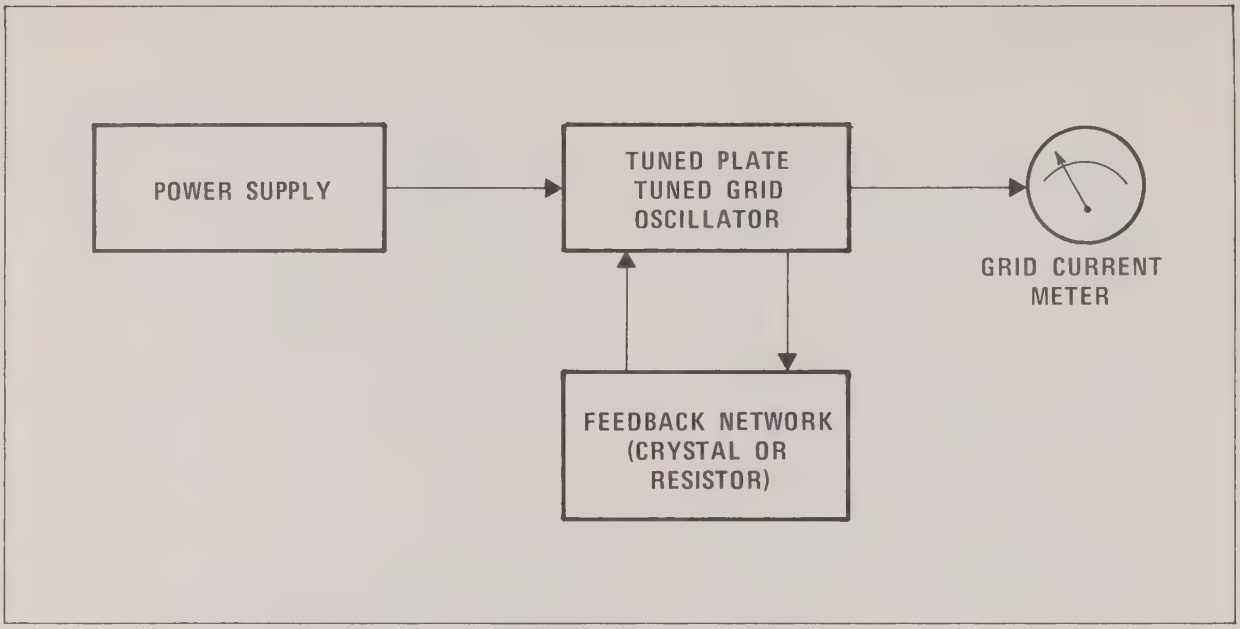
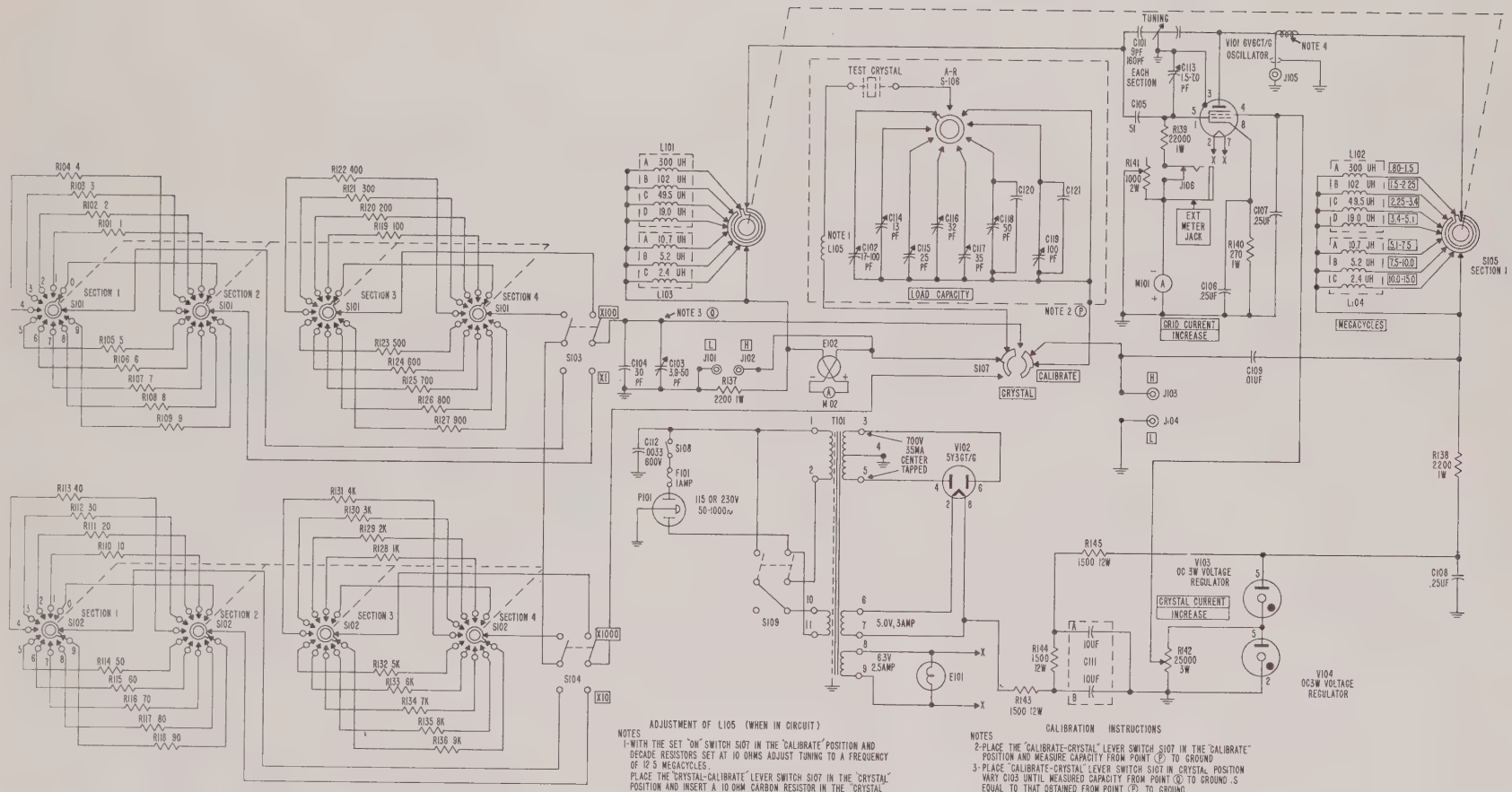


Figure 4. Block Diagram Of Crystal Impedance Meter Model 459B.

g. **Block Diagram** — Crystal Impedance Meter Model 459B measures the equivalent impedances of a communication piezoelectric crystal in the frequency range of 0.8 to 15.0 mc. The equipment consists of a single r-f pentode tube oscillator, a feedback network and a conventional power supply (Figure 4). The crystal under test or a decade resistor can be made a part of the feedback network. The magnitude of the voltage oscillations of the tube is indicated by GRID CURRENT meter.

h. **General** — To cover the frequency range of 0.8 to 15.0 mc, provision is made to switch various inductance elements into the circuit (Figures 5 and 6). The tuned plate circuit is coupled to the tuned grid circuit by means of a coupling network of which a piezoelectric crystal can be made a part. The circuit is tuned approximately to the resonant frequency of the crystal unit, with the crystal unit in the coupling network. The circuit oscillates near the resonant frequency of the crystal unit, at which point the crystal impedance is resistive. The resistance decade is then switched into the circuit and adjusted to give the same magnitude of oscillation; the TUNING dial is varied to obtain the same frequency as with the crystal unit. This resistance value is then equivalent to the resonant resistance of the crystal unit. The position markings on the decade resistor indicate the resistance value of the crystal. For anti-resonant measurements, a calibrated capacitor (LOAD CAPACITY) is switched in series with the crystal unit, and the circuits are adjusted in the same manner as for resonant operation. The resistance thus determined is the anti-resonance resistance of the crystal unit operating into the selected load capacitance. Microammeter M101, in the grid circuit of oscillator tube V101, indicates the magnitude of oscillation. The magnitude of oscillation can be varied by means of the CRYSTAL CURRENT control (Figure 2).

i. **Power Supply** — The power supply (Figure 5) is a conventional type that converts 115 or 230 volt a-c, 50 to 1,000cps to the regulated d-c voltage necessary for the plate and screen of oscillator tube V101. Input fuse F101 is rated at 1 amp, 250 volts. Power switch S108 controls the a-c power to the equipment. Transformer T101 has a primary rating of 115 or 230 volt a-c with output windings on the secondary of 700 volts at 35ma (milliamperes) center tapped, 5.0 volts at 3 amp for the filament of V102 (5Y3GT rectifier tube), and 6.3 volts at 2.5 amp for the filament of V101 (6V6GT oscillator tube) and pilot lamp E101. The output of V102 is filtered by resistors R143, R144, and R145, and capacitors C111A and C111B. The d-c voltage for the plate of V101 is controlled by resistor R145 and voltage-regulator tubes V103 and V104 (type OC3). The screen of V101 is supplied with voltage controlled by potentiometer R142 (CRYSTAL CURRENT control). This screen voltage controls the amplitude of the r-f oscillations. Pilot lamp E101 is operated from the 6.3 volt tap of transformer T101. The .003μF (microfarad) capacitor C112 bypasses r-f from the input power line to ground. The .25μF capacitor C108 blocks r-f from the power supply. The 115/230 volt switch S109 permits the switching of the primary windings of T101 for either 115 or 230 volt operation.



ADJUSTMENT OF L105 (WHEN IN CIRCUIT)

NOTES

1-WITH THE SET "ON" SWITCH SI07 IN THE "CALIBRATE" POSITION AND DECADE RESISTORS SET AT 10 OHMS ADJUST TUNING TO A FREQUENCY OF 12.5 MEGACYCLES.
PLACE THE "CRYSTAL-CALIBRATE" LEVER SWITCH SI07 IN THE "CRYSTAL" POSITION AND INSERT A 10 OHM CARBON RESISTOR IN THE "CRYSTAL" SOCKET COMPRESS OR EXTEND L105 UNTIL THE FREQUENCY OBTAINED IN "CRYSTAL POSITION IS EQUAL TO THAT IN THE CALIBRATE POSITION

CALIBRATION INSTRUCTIONS

NOTES

2-PLACE THE "CALIBRATE-CRYSTAL" LEVER SWITCH SI07 IN THE "CALIBRATE" POSITION AND MEASURE CAPACITY FROM POINT (P) TO GROUND
3-PLACE "CALIBRATE-CRYSTAL" LEVER SWITCH SI07 IN CRYSTAL POSITION VARY C103 UNTIL MEASURED CAPACITY FROM POINT (Q) TO GROUND .5 EQUAL TO THAT OBTAINED FROM POINT (P) TO GROUND
4-WITHOUT REMOVING INSULATION FROM EITHER WIRE MAKE AT LEAST 2 1/2 TURNS OF LEAD FROM JI05 AROUND PLATE LEAD FROM VI01
5 RI01 TO RI36 INCL SHALL BE 1/2 WATT 1% TOLERANCE RESISTORS
6-SWITCHES SI01, SI02 AND SI05 ARE VIEWED FROM END OPPOSITE CONTROL KNOB, SECTIONS DESIGNATED 1 ARE NEAREST THE KNOB END.
7-UNLESS OTHERWISE SHOWN RESISTORS ARE IN OHMS

Figure 5. Over-all Schematic Diagram Of Crystal Impedance Meter Model 459B.

j. **Oscillator** — (1) The frequency bands of oscillator tube V101 are changed by switching (using MEGACYCLES switch S105) inductances L102A, B, C, D, and L104A, B, C, into the plate tank circuit, and L101A, B, C, D, and L103A, B, C into the grid circuit. For each band, the r-f coil connected to the plate has the same inductance as the r-f coil connected to the grid. The frequency range covered is 0.8 to 15.0mc in seven ranges. The tuning in each band is accomplished with variable, dual section capacitor C101 (TUNING control) of 7.8 to 160$\mu\mu$F for each section.

(2) The 51$\mu\mu$F capacitor C105 couples the grid of V101 to the tuning coils. The charging current of this capacitor is measured by means of 0 to 200μA (microampere) meter M101 (GRID CURRENT). The sensitivity of M101 is adjusted by varying the 1,000 ohm shunt potentiometer R141 (GRID CURRENT control). The greater the voltage of oscillation on the grid of V101, the greater the reading of meter M101. The magnitude of oscillation is controlled by varying the voltage on the screen grid of V101 with the 25,000 ohm potentiometer R142 (CRYSTAL CURRENT control).

k. **Feedback Network** — The feedback network (Figure 6) consists of two sections: the crystal socket assembly and the resistance substitution decade. The lever switch S107 (CALIBRATE-CRYSTAL) connects either one section or the other to the oscillator. The .01μF capacitor C109 couples the moving arm of switch S107 to the 2,200 ohm, r-f dropping resistor R138 which is in series with the tuned plate inductance of V101. The 2,200 ohm resistor R137 is in series with the tuned grid inductance of V101. The r-f current flowing through the crystal or through the substitution decade resistors injects a voltage of the proper phase for oscillation into the grid circuit across R137. Switch S106 (LOAD CAPACITY) is mounted in the crystal socket assembly and allows the selection of the calibrated anti-resonance load capacitor. Inductance L105 (1 to 4 turns of air core, self-supporting wire) adjusts the frequency of oscillation at CRYSTAL position (see Maintenance, para. 3). The resistance substitution network consists of resistors R101 through R136 with decade resistor switches S101 and S102, and toggle switches S103 and S104 to vary the substitution resistance from 0 to 9,900 ohms in 1-ohm steps. The resistance decades are switched into the oscillator circuit and adjusted to obtain the same amplitude of oscillation as the oscillating crystal unit. The switch positions of the decades then indicate the resistance. The magnitude of the crystal current is measured by means of meter M102 and thermocouple E102. The fixed 30$\mu\mu$F capacitor C104 and the variable 5 to 42$\mu\mu$F capacitor C103 are connected between the resistance decades and ground and compensate for the capacitance of the crystal socket assembly to ground. The crystal socket assembly and the box shield around it are insulated from ground. The crystal socket assembly will accommodate any two-pin crystal unit with a center-to-center pin spacing of .5 to 1.25 inches; crystal holders similar to type FT-249 may be tested. The crystal holder adds a minimum of capacitance across the crystal.

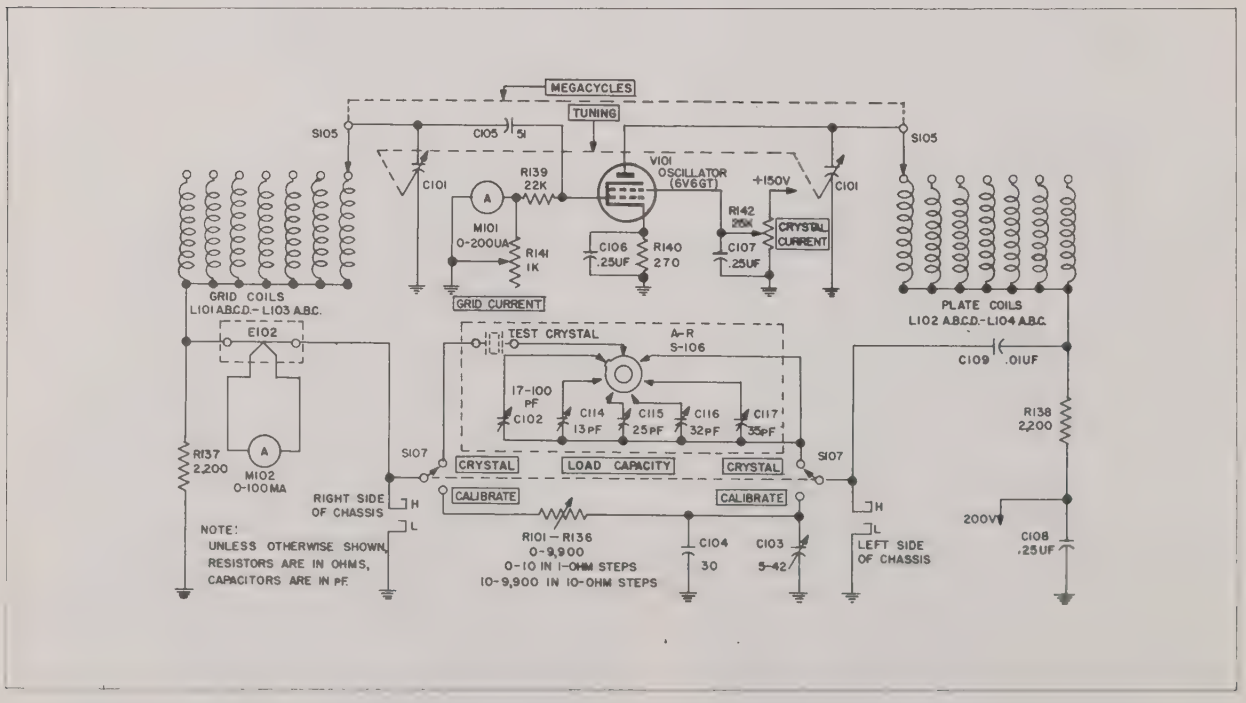


Figure 6. Schematic Diagram of Feedback Network

MAINTENANCE

1. General

Periodic inspection should be made to see that all screws and nuts are tight. If trouble should develop in the sealed meters M101 and M102, they should be replaced from the factory and no attempt made to repair them.

If the tuning dial should become loose and slip, it is only necessary to rotate the variable capacitor to its maximum capacity and align the dial at the zero mark.

The LOAD CAPACITOR dial is more critical and should it become loose and slip it is necessary to recalibrate the capacitor. Since the capacitor is calibrated to better than ±1pF the C. I. Meter is best sent back to the factory for recalibration unless proper calibration equipment is available.

2. Readjustment of Capacitor C103

The capacitance from point P (Figure 9) to ground (with CALIBRATE-CRYSTAL switch S107 in the CALIBRATE position) must equal that of point Q (Figures 6 and 8) to ground (with switch S107 in the CRYSTAL position). Capacitor C103 (Figure 8) must be varied until these capacitance values are equal. These capacitances are measured (Figure 9) by use of Q Meter TS-617A/U and a 110-1, 100pF precision capacitor (type 722-D, General Radio Co., or equal). A crystal-controlled, 400-kc frequency generator (oscillator) must be used to stabilize the frequency of the Q-meter; a standard inductance coil must be used to tune the Q-meter to resonance. Connect these units together as shown in Figure 9, using No. 12 AWG solid copper wire, spaced on 2-inch centers, and coaxial cable. The exposed ends of the coaxial cable should be as short as possible and should be the same length for each measurement.

a. **Measurement of Capacitance from Point P to Ground**
Place the CALIBRATE-CRYSTAL switch S107 (Figure 9) in the CALIBRATE position, switch S106 to R, short the crystal socket as shown in Figure 9 and proceed as follows:

1. Connect the inner conductor of one end of the coaxial cable to the HIGH terminal and the outer conductor to the G terminal of the precision capacitor.

2. Connect the ground terminal on the precision capacitor to a good ground such as a water pipe, a steam pipe, or a BX electrical cable if it is well grounded. Errors due to capacitance between the equipment being tested and the tester's body thus will be minimized.

3. Connect a banana plug to the outer conductor and insert it into jack J101 (Figure 10). Place the inner conductor, at the other end of the coaxial cable, near (within ¼-inch) one of the rivest (point P) that hold the crystal socket.

4. Set the precision capacitor to 200pF and tune the Q-meter to resonance (maximum deflection of voltmeter on Q-meter) by using a standard inductance coil (Figure 10).

5. Connect the wire (3. above) to point P (Figure 14). Turn the precision capacitor dial until resonance is reached again.

6. Read the capacitance value indicated on the precision capacitor.

7. The capacitance value of P to ground is the difference between 200pF and the new setting (6. above) of the precision capacitor dial. Note the difference.

b. **Measurement of Capacitance from Point Q to Ground**

1. Set the switches (Figure 9) as follows:

   a. CALIBRATE-CRYSTAL switch S107 to CRYSTAL.

   b. Switches S101 to S102 to 0.

   c. Switch S103 to X1.

   d. Switch S104 to X10.

2. Disconnect the inner conductor and the banana plug from the rivet and jack J101. Reconnect these conductors to point Q as follows:

   a. Stand the C. I. Meter on its end and insert the banana plug on the outer conductor into jack J104 (Figure 9 and Figure 10).

   b. Remove the button on the bottom plate and insert the inner conductor through the hole. Place the conductor near (within ¼-inch) the stud mounted on capacitor C103. Do not remove the bottom plate for this operation.

3. Set the precision capacitor to 200pF and tune the Q-meter to resonance, using the standard inductance coil (Figure 10).

4. Insert the wire into the hole in the stud of capacitor C103 and rotate the precision capacitor dial until resonance is reached again.

5. Read the capacitance value indicated on the precision capacitor.

6. The capacitance value of Q to ground is the difference between 200pF and the new setting of the precision capacitor dial. Note the difference.

7. If the capacitance value of point Q to ground (6. above) is different from that at point P to ground (a. 7. above), adjust capacitor C103 (the top cover may be removed for this adjustment) with a non-metallic screw driver until the measured capacitance from point Q to ground is equal to the capacitance measured from point P to ground.

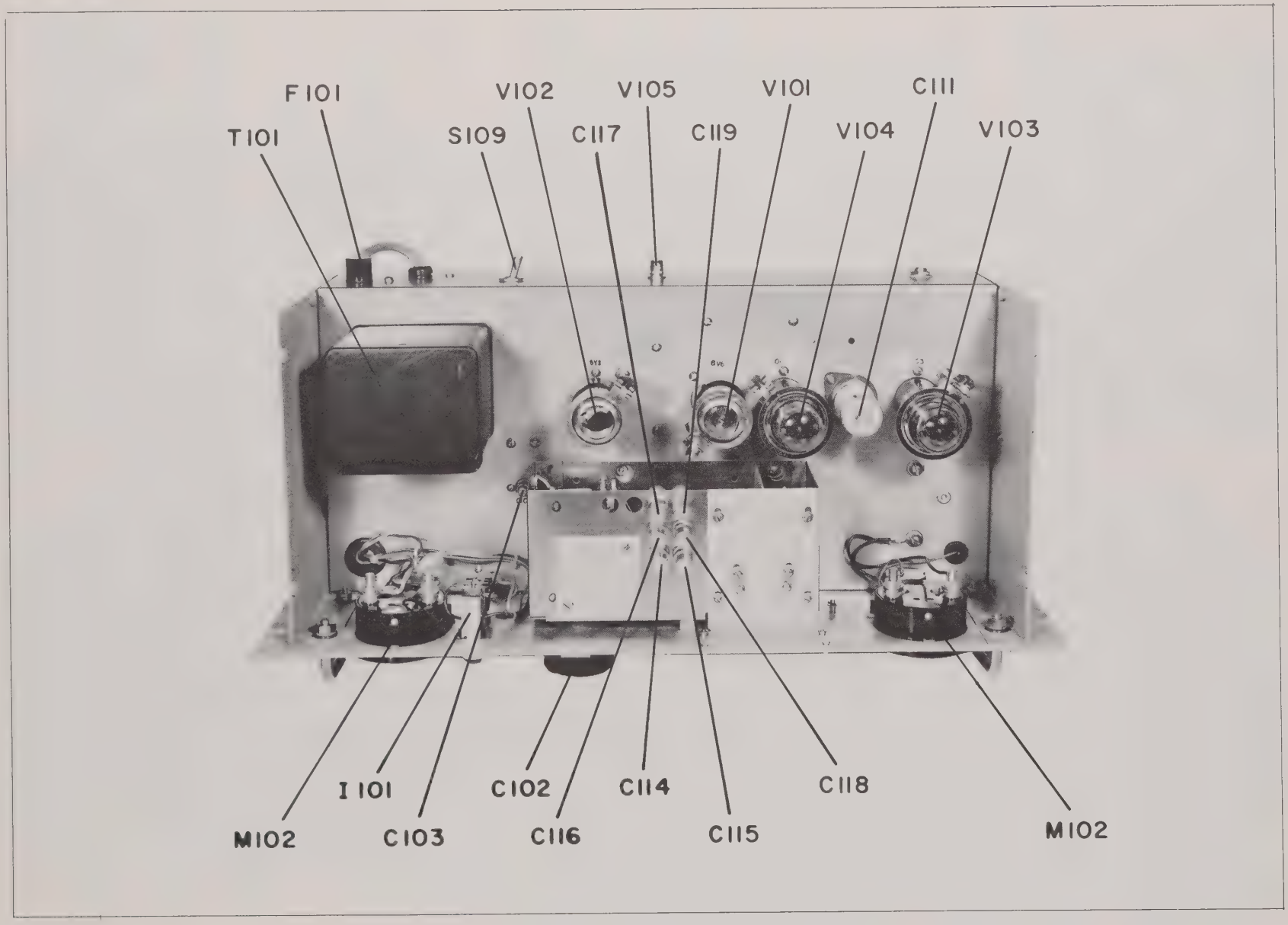


Figure 7. Top View Of Panel And Chassis Assembly.

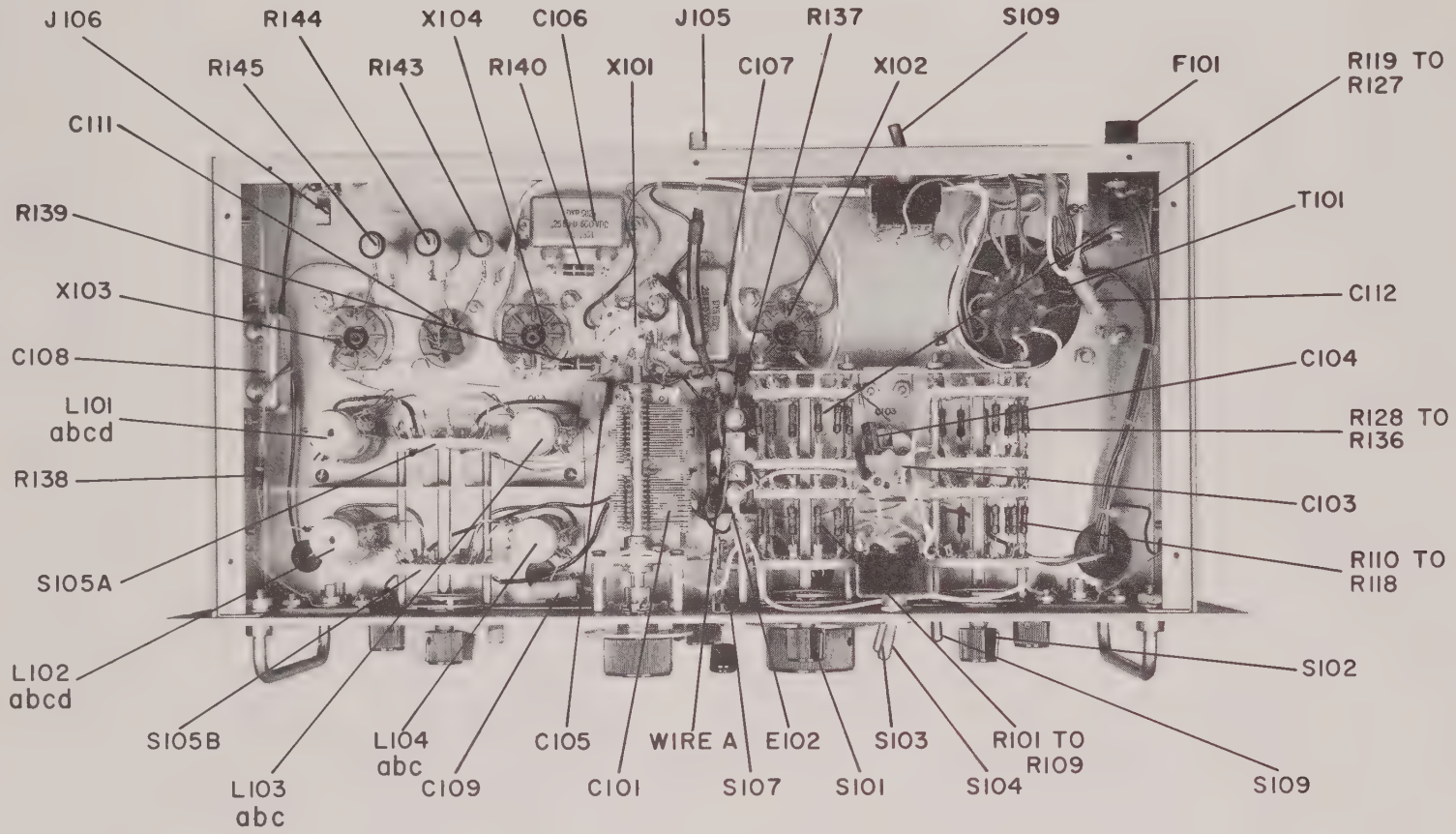


Figure 8. Bottom View Of Chassis Assembly.

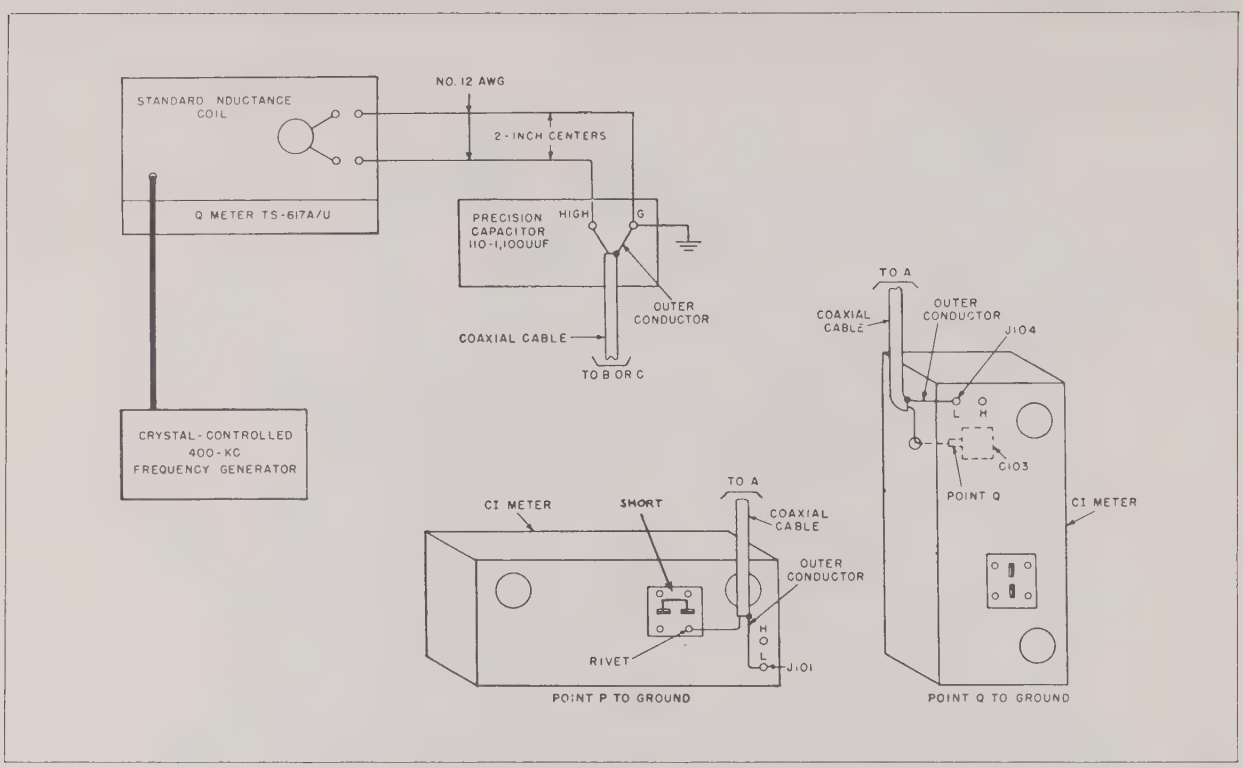


Figure 9. Test Circuit For Measurement Of Points P And Q To Ground.

3. Checking Decade Resistors

The dc resistance value of the decade resistors should be measured as instructed below. Measurements must be taken in 1-ohm steps from 10 ohms through 19 ohms; in 10-ohm steps from 20 ohms through 90 ohms; in 100-ohm steps from 100 ohms through 900 ohms; and in 1,000-ohm steps from 1,000 ohms through 9,000 ohms.

NOTE: *Since these resistors are noninductive, their resistance values at the applicable frequency are essentially the same as their dc resistance value.*

a. Connect terminals X1 and X2 of Resistance Bridge ZM-4B/U to jacks J102 and J103 of the C. I. Meter (Figure 9) with No. 12 AWG bare wire. These wires should be as short as possible.

b. Set the controls of the C. I. Meter as follows:

1. Switch S108 to OFF.
2. Switch S107 to CALIBRATE.
3. Switches S101 through S104 to indicate 10 ohms.

NOTE: *Settings of all other controls are unimportant for these measurements.*

c. Measure the dc resistance value of the indicated setting with Resistance Bridge ZM-4B/U.

NOTE: *The measured value should be within ±3% for 1 and 2 ohms and within ±2% of the remaining values indicated by decade switches S101 through S104.*

d. Set decade switches S101 through S104 to the next setting to be measured.

e. Repeat c. above.

f. Repeat d. and e. above until all measurements have been made

4. Measurement and Adjustment of Frequency

The actual frequency ranges of the C. I. Meter should be equal to, or greater than, those given in table 5-1. Measure the frequency ranges being checked as instructed below.

NOTE: *The frequency overlap can be adjusted only by adding or removing turns from the appropriate tuned plate inductance coil or tuned grid inductance coil, or by replacing the coil. If a replacement coil is available do not attempt to adjust the overlap by adding or removing turns from the coils in the C. I. Meter.*

a. Connect the C. I. Meter to Frequency Meter Set SCR-211 or similar frequency measuring equipment with rf cable assembly W101.

b. Set switch S106 to the S position, switch S107 to the CRYSTAL position, and switch S108 to the ON position. Allow 15 minutes for the C. I. Meter to warm up.

c. Turn MEGACYCLES switch S105 to the range being measured.

d. Insert the leads of a 1-watt carbon composition resistor into the crystal socket as far as they will go. The resistor leads should be ½-inch long. The value of the resistor should be within ±1% of the value given in the table below when measured on Resistance Bridge ZM-4B/U.

e. Turn TUNING dial I103 to the O position and perform the operations described below.

1. Adjust GRID CURRENT control E104 to correct an off-scale deflection of meter M101, if necessary.
2. Adjust CRYSTAL CURRENT control E105 until the value of crystal current given in the table below is shown on Meter M102.
3. Tune Frequency Measuring Set SCR-211, or equivalent, to the C. I. Meter frequency.
4. Compare the measured frequency with the frequency given in the table below. It should be equal to, or below, the frequency given.

f. Turn TUNING dial I103 to the 100 position and proceed as follows:

1. Perform the operations described in e. 1. through 3. above.
2. Compare the measured frequency with the frequency given in the table below. It should be equal to, or above, the frequency given.

5. Frequency Correlation Between Crystal and Calibrate Positions

Check the frequency correlation between CRYSTAL and CALIBRATE positions of the CRYSTAL-CALIBRATE switch S107 (Figure 9) as follows:

NOTE: *Connect the C. I. Meter to frequency measurement device or any radio receiver capable of this frequency.*

a. Insert the leads of a 15-ohm 1-watt carbon composition resistor into a crystal socket as far as they will go. The resistor should have ½-inch leads. The resistance value should be within ±1% when measured on Resistance Bridge ZM-4B/U or equal.

TABLE 5-1 TABLE OF DECADE RESISTOR VALUES

RANGE (MC)	RESISTANCE (OHMS)	CRYSTAL CURRENT (MA)	TUNING DIAL I103	
			0 POSITION MAX. VALUE (MC)	100 POSITION MIN. VALUE (MC)
0.8 - 1.50	1,000	10	0.795	1.51
1.50 - 2.25	470	20	1.3	2.29
2.25 - 3.40	220	10	2.0	3.42
3.40 - 5.10	120	15	2.8	5.2
5.10 - 7.50	56	20	4.0	7.7
7.50 - 10.00	22	25	5.0	10.2
10.00 - 15.00	15	40	8.0	15.2

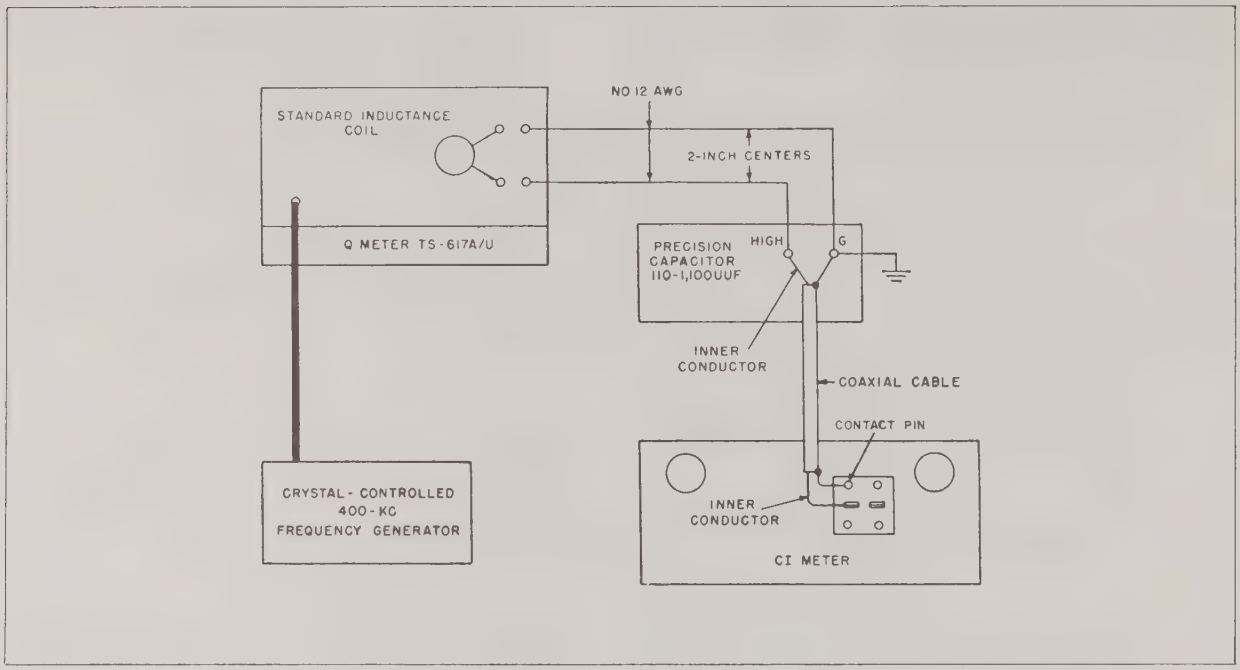


Figure 10. Test Circuit For Calibration Of Load Capacity Dial.

b. Set the controls on the C. I. Meter as instructed below.
   1. MEGACYCLES switch S105 to 10.00-15.00.
   2. Switch S106 to S.
   3. Switch S104 to X10.
   4. Switch S102 to 1.
   5. Switch S103 to X1.
   6. Switch S101 to 5.
   7. CRYSTAL CURRENT control R142 and GRID CURRENT control R141 to maximum counter-clockwise position.
   8. LOAD CAPACITY dial C102 to 25.
   9. Switch S108 to ON. Allow 15 minutes for the C. I. Meter to warm up.

c. Push the CALIBRATE-CRYSTAL switch S107 to CALIBRATE.

d. Adjust CRYSTAL CURRENT control R142 until a value of 20 milliamperes is indicated on meter M102.

e. Adjust GRID CURRENT control R141 to correct an off-scale deflection of meter M101, if necessary.

f. Adjust the CIM to 12mc as read on the counter or as zero beated on the receiver.

g. Adjust TUNING dial C101 on the C. I. Meter until a zero beat is obtained if receiver is used.

NOTE: Repeat d., e., and g., above, if necessary.

h. Set switch S107 to the CRYSTAL position.

i. Retune the receiver until a zero beat is obtained. Note the audio output frequency. The difference in the noted frequency and 12 megacycles, caused by moving switch S107 to the CRYSTAL position, should be less than 4 kilocycles.

j. If the difference in frequency is greater than 4 kilocycles, perform the operation described below.
   1. Adjust GRID CURRENT control R141 to the maximum clockwise position.
   2. Adjust CRYSTAL CURRENT control R142 until a reading of 150μA is indicated on meter M101.
   3. Adjust capacitor C113 to obtain a minimum difference in grid current readings between the CALIBRATE and CRYSTAL positions of switch S107. There are two solder dots on capacitor C113: one on the stationary disk and one on the movable disk. Turn the disk until these dots are on opposite sides. Capacitor C113 is now at its minimum value. Slowly increase the capacitance until the change of GRID CURRENT on

meter M101 (Figure 9), when switch S107 is moved from the CALIBRATE to the CRYSTAL position, is at a minimum. Usually, setting capacitor C113 at one-third of its maximum value is satisfactory for all units. The values of grid current indicated on meter M101 must not vary more than ±3% or 4.5μA from 150μA.

4. Repeat the operations described in c. through i. above.

k. If the difference frequency is still greater than 4 kilocycles, it will be necessary to adjust coil L105 (Figure 5.) Adjust coil L105 by compressing or extending the length of the coil until the difference in frequency is less than 4 kilocycles with the C. I. Meter operated as instructed in c. through i. above.

NOTE: Coil L105 has a diameter of ½-inch and consists of 1 to 4 turns of No. 16 AWG tinned copper wire connected to one of the crystal unit socket terminals. Coil L105 is present only in those C. I. Meters which require it.

6. Load Capacitance

The load capacitors are measured with the LOAD CAPACITY switch in the proper position.

The equipment required is a 400kc crystal oscillator controlling a Q Meter (Boonton Radio Type 100-A, or equal) and a precision capacitor (General Radio Type 722-D, or equal traceable to the Bureau of Standards calibration). The wiring between the units must be #12 AWG solid copper wire supported on 2 inch centers. The connections to the C. I. Meter are as follows: the ground lead of the precision capacitor goes to the pin of the socket face and the high lead goes to the left contact of the crystal socket.

The connection to the left contact of the crystal socket is pulled out a small amount so as to break contact with the C. I. Meter. The Q Meter is then tuned to resonance using a standard 1mH inductance coil with the General Radio precision capacitor set at 250pF. Allow the Q Meter to warm up for 30 minutes, retune the Q Meter and subtract the value of pF desired in the load capacitor from 250pF, then set the General Radio capacitor dial to that value. Connect the lead to the C. I. Meter and adjust the precision load capacitor of the C. I. Meter for peak resonance on the Q Meter. Repeat for each value of load capacity starting with an accurate setting at 250pF on the General Radio dial.

The variable 17-100pF capacitor is set by turning the capacitor shaft until the load capacity is at maximum capacity as obtained by the above procedure. Set the dial to 100pF and mount it to the shaft taking care to hold the shaft and capacitor fixed with the finger placed through the hole provided in the top of the load capacitor box. Tighten the dial set screws to shaft lightly. This is one of many methods. Any method may be used as long as accuracy is maintained.

7. Oscillation Test

With CRYSTAL-CALIBRATE switch S107 in the CRYSTAL position (no crystal in socket), rotate TUNING knob controlling capacitor C101 through 180° for each band switch position with R141 and R142 advanced in their extreme clockwise direction. No self-controlled oscillation should be observed either by an indication of grid current other than residual grid current, or by the presence of a signal on a communication receiver. The condition of oscillation can be eliminated by proper placement of grid and plate circuit wiring. In the replacement of parts and repairs these wires may have been disarranged. Wire A (Figure 8) is very sensitive and must be replaced within 1/16 of an inch; a small movement of this wire will put the equipment into a condition of oscillation.

8. Troubleshooting

WARNING: *When servicing the Crystal Impedance Meter be extremely careful. High voltage is present. Always disconnect the line plug before making resistance checks in the meter. Before touching any part after the voltage is shut off, short the part to chassis.*

a. **Troubleshooting Procedures**

1. **Specialization and Localization** — The first step in servicing defective test equipment is to sectionalize the fault. Sectionalization means tracing the fault to the major component or circuit responsible for the abnormal operation of the set. The second step is to localize the fault. Localization means tracing the fault to the defective part responsible for the normal condition. Some faults, such as burned out resistors and shorted transformers, can be located by sight or smell. The majority of faults may be located by checking voltage and resistance.

2. **Tests** — The tests listed below aid in isolating the source of trouble. Remember that servicing procedure should cause no further damage to the test equipment. First, trouble should be localized to a single stage or circuit in the equipment. Then the trouble may be isolated within that stage or circuit by appropriate voltage, resistance, and continuity measurements.

   Through this inspection alone the repairman frequently discovers the trouble or determines the stage in which the trouble exists. This inspection is valuable in order to avoid additional damage which might occur through improper servicing methods and to forestall future failures.

3. **Operational Tests** — The operational tests are important because they frequently indicate the general condition of trouble. In many instances this information will indicate the exact nature of the fault. In order for this information to be utilized fully, all symptoms must be interpreted in relation to another.

The troubleshooting symptoms listed in the chart on page 21 will aid in localizing trouble.

4. **Intermittents** — In all these tests the possibility of intermittents should not be overlooked. This type of trouble may appear when the set is tapped or jarred. Look for loose connections. It is possible that the trouble is not in the set itself but in the installation, such as cord connections, etc.

9. Voltage Measurements

Voltage measurements are an almost indispensable aid to the repairman because most trouble either results from abnormal voltages or produces abnormal voltages. Voltage measurements are always made between two points in the circuit and the circuit need not be interrupted. Complete information on normal operating voltages are given in Figure 11.

1. Unless otherwise specified, voltages are measured between the indicated points and ground.
2. Always begin by setting the voltmeter on the highest range in order that the voltmeter will not be overloaded and then, if necessary, set the voltmeter to a lower range.
3. In checking cathode voltage remember that a reading can be obtained when the cathode resistor actually is open. The resistance of the meter may act as the cathode resistor; thus, the cathode voltage may be approximately normal only as long as the voltmeter is connected between cathode and ground. An abnormally high plate voltage may indicate an open cathode resistor.

10. Voltmeter Loading

It is essential that the voltmeter resistance be at least ten times as large as the resistance of the circuit across which the voltage is measured. If the voltmeter resistance is comparable to the circuit resistance, the voltmeter will indicate a voltage lower than the actual voltage present when the voltmeter is removed from the circuit.

1. To minimize voltmeter loading in high resistance circuits, use the highest voltmeter range. The decreased loading caused by the voltmeter will more than compensate for the inaccuracy which results from reading only a small deflection on the scale of the voltmeter.
2. The voltage and resistance charts, Figure 11 and Table 5-3, are based on readings taken with a 20,000 ohms per voltmeter. If a 20,000 ohms per voltmeter is used in testing for the voltage, it is not necessary to consider the effect of loading.

11. Resistance Measurements

When a fault develops in a circuit its effect will very often show up as a change in the resistances values. Figure 11 indicates the normal resistance values as measured at the tube sockets. These values are measured between the indicated points and ground unless otherwise stated. Before making any resistance measurements, turn off the power. If the ohmmeter is connected to a circuit which already has voltage in it, the meter may be damaged.

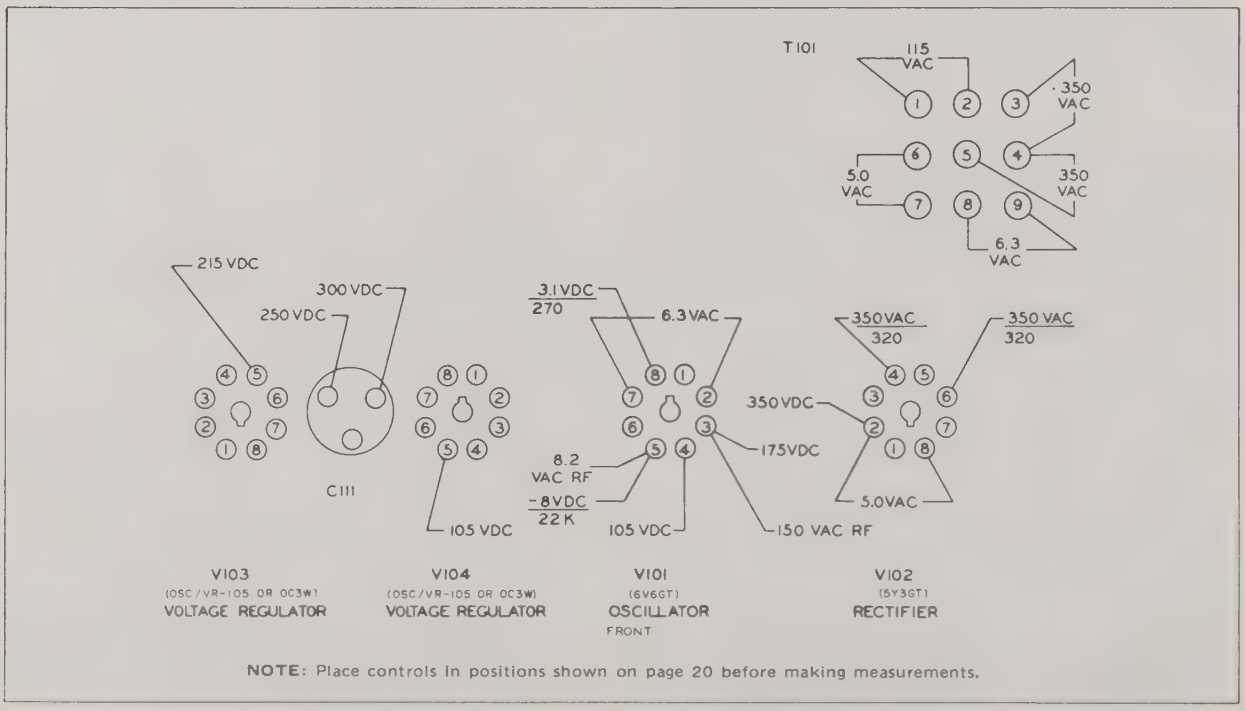


Figure 11. Socket Voltage And Resistance Diagram.

CONTROL	POSITION	CONTROL	POSITION
CALIBRATE CRYSTAL	CALIBRATE	LOAD CAPACITY	R
X1 – X100	0	GRID CURRENT	Full counterclockwise
X10 – X1000	0	MEGACYCLES	0.8 – 1.50
CRYSTAL CURRENT	Full clockwise	TUNING	50

NOTES: *All voltages to chassis unless otherwise indicated. Resistance values measured with power off equipment. Unless otherwise shown, resistances are in ohms.*

CAUTION: *Always discharge high voltage capacitors before making resistance measurements.*

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12. Tube Checking

Tube faults are responsible for a large percentage of the failures which occur in test equipment. In putting a new tube into the oscillator circuit, it may be necessary to re-align the oscillator.

13. General Precautions

Whenever the C. I. Meter is serviced, carefully observe the following precautions:

a. Be careful when the instrument is removed from its cabinet, dangerous voltages are exposed.

b. Careless replacement of parts often causes new faults. Therefore, observe the following points:

1. Before a part is unsoldered, note the position of the leads. If the part, such as a transformer, has a number of connections, tag each of the leads to it.
2. Be careful not to damage other leads by pulling or pushing them out of the way.
3. Do not allow drops of solder to fall into the set since they may cause short circuits.
4. A carelessly soldered connection may create a new fault. It is very important to make well soldered joints since a poorly soldered joint is one of the most difficult faults to find.

14. Troubleshooting Chart

The following chart is supplied as an aid in locating trouble in the C. I. Meter. This chart lists the symptoms which the repairman observes while making a few simple tests. The chart also indicates how to localize trouble quickly to individual stages of the C. I. Meter. Once the trouble has been localized to a stage or circuit, voltage and resistance measurements of this stage or circuit ordinarily should be sufficient to isolate the defective part. Normal voltage and resistance measurements are given in Figure 11.

TABLE 5-2 TROUBLESHOOTING CHART

SYMPTOM	POSSIBLE TROUBLE	CORRECTION
1. Pilot lamp does not light.	a. Cord not plugged into source or open.	a. Check at source and at unit (terminals No. 1 and 2 on T101).
	b. Fuse blown out.	b. Check and replace.
	c. Transformer T101 open.	c. Check and replace.
	d. Pilot lamp burned out.	d. Check and replace.
2. Voltage regulator tubes do not light.	a. Rectifier tube V102 is faulty.	a. Replace.
	b. High voltage winding of T101 is open.	b. Check and replace.
3. No apparent reading or change of GRID CURRENT meter.	a. Oscillator tube V101 not oscillating.	a. Check and replace tube.
	b. Crystal current too high.	b. Check operational procedure, increase GRID CURRENT control to maximum sensitivity, and decrease the CRYSTAL CURRENT control.
	c. Wiring shorted.	c. Check continuity.
	d. Meter open.	d. Check and replace meter.
	e. Transformer open.	e. Measure a-c and d-c voltages shown in Figure 11.
	f. R-f coil open.	f. Measure a-c and r-f voltages shown in Figure 11.
	g. CRYSTAL CURRENT potentiometer R142 open.	g. Check voltage on pin No. 4 of tube V101 as control is varied. Replace control if faulty.
	h. Oscillator coil open.	h. Check all ranges on CALIBRATE position. Replace faulty coil.
4. Oscillation without crystal in socket. S-107 in CRYSTAL position.	a. Wiring disturbed.	a. Move wire A (Figure 8) until oscillation stops.

15. Resistance Chart

The d-c (direct-current) resistances of T101 and V101 should correspond to those listed below. Refer to Figure 11 for the socket voltages and resistances of T101, V101, V102, V103, and V104.

TABLE 5-3 RESISTANCE CHART

TRANSFORMER OR TUBE	TERMINALS OR PINS	RESISTANCE (ohms)
T101	1–2	6.0
	3–4	320
	4–5	320
	6–7	less than 1
	8–9	less than 1
	10–11	6.0
V101	1–GND	0
	2–GND	INF
	3–GND	INF
	4–GND	25,000
	5–GND	22,000
	7–GND	INF
	8–GND	270

16. Localizing Troubles

Check the d-c and filament voltages on the socket pins of V101 (Figure 11). Correct voltages here indicate the proper operation of the power supply. Be sure to place the controls in positions given on page 20. Measure the r-f voltages on the socket pins of V101 (Figure 11). Correct r-f voltages indicate operation of the tuned circuits and tube V101. If voltages appear correct, refer to the wiring diagram (Figure 12), and check the crystal holder network and the decade resistor assembly for wiring continuity or shorts to chassis.

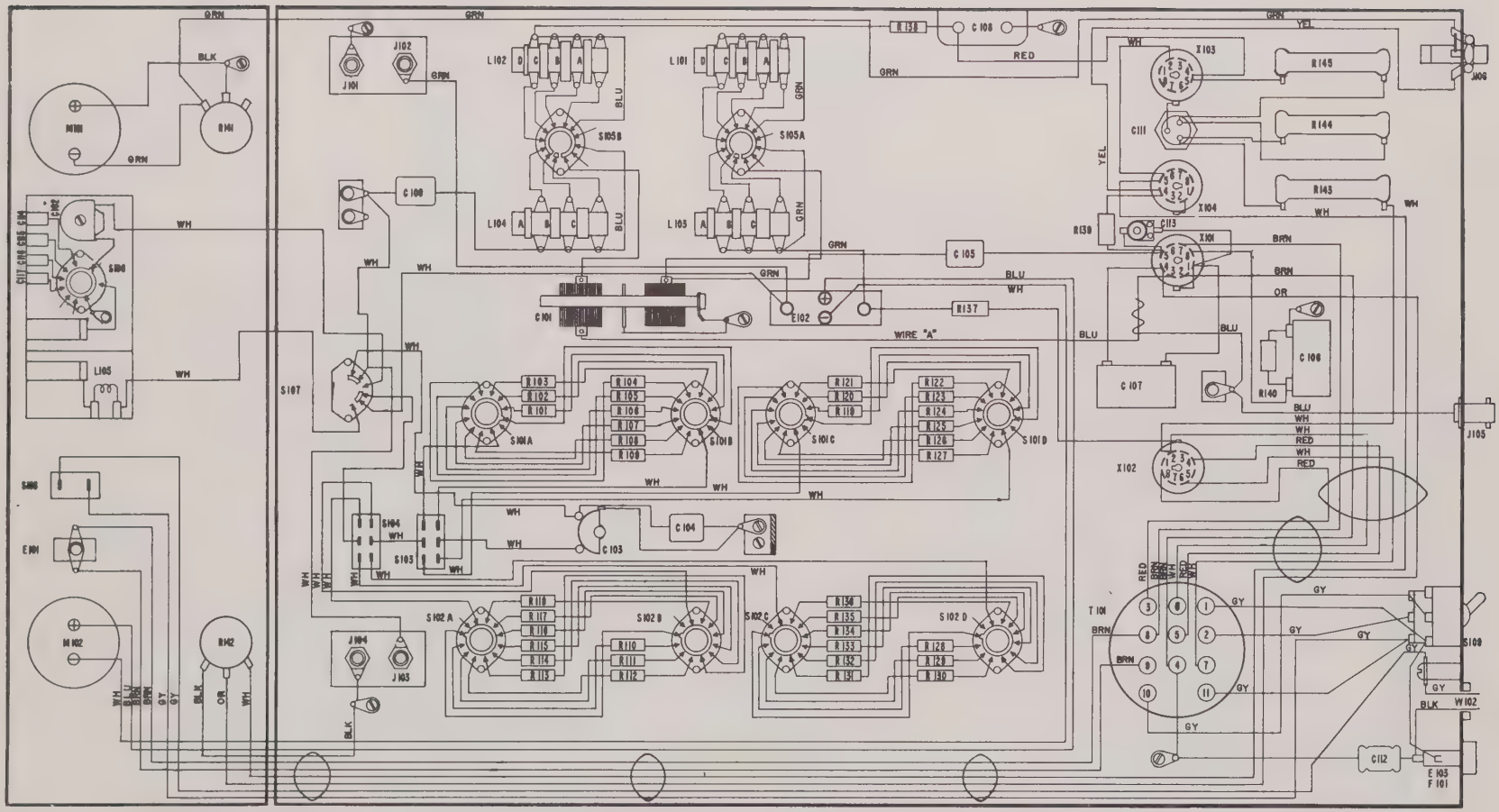

Figure 12. Wiring Diagram

TABLE 5–4 TABLE OF REPLACEABLE PARTS

SYMBOL	DESCRIPTION	FUNCTION	RFL PART NO.
W102	CABLE ASSEMBLY, power: type S, 2 cond., No. 16 AWG; 78" o.a. excluding terminations; male plug assembled on one end.	Connects C. I. Meter to 115 volt or 230 volt a-c power source.	HB-29671
W101	CABLE ASSEMBLY, radio-frequency pick-up: cable; 5 ft. excluding terminations; RG-58C/U assembled on one end.	Provides connection to external frequency meter.	HB-6775
C104	CAPACITOR, fixed: mica dielectric; 30pF ±5%; 500 vdcw.	Compensates for P to GND capacity.	H-1080-22
C105	CAPACITOR, fixed: mica dielectric; 51pF ±5%; 500 vdcw.	Couples the grid of V101 to tuning coils.	H-1080-20
C106	CAPACITOR, fixed: paper dielectric; .25μF ±10%; 600 vdcw.	Bypasses cathode of V101.	HA-3747
C107	CAPACITOR, fixed: Same as C106.	Bypasses r-f from screen of V101.	
C108	CAPACITOR, fixed: Same as C106.	Blocks r-f from the power supply.	
C109	CAPACITOR, fixed: mica dielectric; .01μF ±10%; 300 vdcw.	Coupling capacitor, V101 plate.	H-1080-19
C111 A & B	CAPACITOR, fixed: electrolytic; 2 sect; 10μF per sect; 450 vdcw.	Filters out of power supply.	HA-33410
C112	CAPACITOR, fixed: paper dielectric; .0033μF ±10%; 600 vdcw.	A-c line filter.	H-1007-35
C114	CAPACITOR, variable: conc., air dielectric; 2-20pF	Load capacitor.	HA-8727
C115	CAPACITOR, variable: conc., air dielectric; 2-20pF max. (plus stray capacitance) .	Load capacitor.	HA-8727
C116	CAPACITOR, variable: conc., air dielectric; 24-35pF max.	Load capacitor.	HA-8726
C117	Same as C116.		
C118	CAPACITOR, variable; Same as C116 with C120 added.		
C119	CAPACITOR, variable: Same as C116 with C121 added.		

SYMBOL	DESCRIPTION	FUNCTION	RFL PART NO.
C120	CAPACITOR, fixed: silver mica; 22pF ±5%; 500 vdcw.		
C121	CAPACITOR, fixed: silver mica; 75pF ±5%; 500 vdcw.		
C101	CAPACITOR, variable: air dielectric; 2 sect; 9.8 to 160pF; 19 plates per sect; 180° rotation.	Tunes the grid and plate coils of V101.	HB-9986
C102	CAPACITOR, variable: air dielectric; single sect; 9.5 to 105pF.	Precision variable load capacitor.	HA-5556
C103	CAPACITOR, variable: air dielectric; single sect; 3.9 to 50pF; 13 plates; 360° rotation.	Compensates P to GND capacity.	HA-3750
C113	CAPACITOR, variable: ceramic; 1.5 to 7.0μμF; 500 vdcw.	Adjusts capacity grid current.	HA-3751
L101	COIL ASSEMBLY, RF: four coils, 300μh, 102μh, 49.5μh, 19.0μh on one form for ranges of 0.8 to 1.5 mc, 1.5 to 2.25 mc, 2.25 to 3.4 mc, and 3.4 to 5.1 mc, respectively.	Grid oscillator coils for ranges between 0.8 and 5.1 mc.	HB-3712
L102	COIL ASSEMBLY, RF: Same as L101.	Plate oscillator coils for ranges between 0.8 and 5.1 mc.	
L103	COIL ASSEMBLY, RF: three coils, 10.7μh, 5.2μh, 2.4μh on one form for ranges of 5.1 to 7.5 mc, 7.5 to 10.0 mc, and 10. 0 to 15.0 mc, respectively.	Grid oscillator coils for ranges between 5.1 and 15.0 mc.	HB-3714
L104	COIL ASSEMBLY, RF: Same as L103.	Plate oscillator coils for ranges between 5.1 and 15.0 mc.	
L105	COIL, RF.	Frequency correlation.	HA-5181
P101	CONNECTOR, male.	Line plug for standard 115/230 volt receptacle.	HA-29671
P102	CONNECTOR: type BNC; RG-58C/U.	Connects W101 to J105.	HA-5956
J101	CONNECTOR, receptacle: single female cont, banana type connector.	Provides for connection of test lead to chassis.	HA-9735
J102	CONNECTOR, receptacle: Same as J101.	Provides for measurement of voltage across the crystal under test.	
J103	CONNECTOR, receptacle: Same as J101.	Provides for measurement of voltage across the crystal under test.	

SYMBOL	DESCRIPTION	FUNCTION	RFL PART NO.
J104	CONNECTOR, receptacle: Same as J101.	Provides for connection of test lead to chassis.	
J105	CONNECTOR, receptacle: UG-1094/U; for 50 ohm r-f cable.	Connects r-f cable assembly W101 to C. I. Meter.	HA-8732
J106	CONNECTOR, receptacle: JJ-089.	Permits the use of an external meter.	HA-3152
I102	DIAL: worked 0 + 100 over 180° arc.	LOAD CAPACITY dial; varies C102.	HA-41626
I103	DIAL: marked 0 to 100 over 180° arc.	TUNING capacitor dial; varies C101.	HA-28922
F101	FUSE, cartridge: 2 amp; 250 v; type 3AG.	Line fuse; protects the C. I. Meter from current overload.	HA-1289
E103	FUSEHOLDER: extractor post type; for single 3AG cartridge fuse; bakelite; 250 v, 15 amp max.	Holds a-c line fuse F101.	HA-1291
E104	INSULATOR, standoff: round post shape; white steatite; 3/4" lg; 3/8" OD with two No. 6-32 tapped holes in each end.	A-c line insulator.	HA-3737
E105	KNOB: round; black; 1/4" shaft; .713" diam.	Knob for GRID CURRENT control; varies R141.	HA-26955
E106	KNOB: Same as E104.	Knob for CRYSTAL CURRENT control; varies R142.	
E107	KNOB: bar; black; 1/4" shaft; 1.15" long	Knob for LOAD CAPACITY switch.	HA-41608
E108	KNOB: Same as E107.	Knob for MEGACYCLES switch.	
E109	KNOB: Same as E107.	Knob for decade resistor switches (2).	
E110	KNOB: round; 1/4" shaft; 1.764" dia.	Knob for LOAD CAPACITY dial.	HA-41609
E111	KNOB; round; 1/4" shaft; 1.25" dia.	Knob for TUNING CAPACITOR dial.	HA-25119
E101	LAMP, incandescent: 6 to 8 v, .25 amp; miniature bayonet base.	Pilot lamp; indicates the presence of line voltage.	HA-3735
I101	LIGHT, indicator: 1/2" diam. red lens; miniature bayonet socket.	Lamp assembly for lamp E101.	HA-3734

SYMBOL	DESCRIPTION	FUNCTION	RFL PART NO.
M101	METER, ammeter: dc, 0 to 200μa; round HS metal case; ±2% accuracy for full-scale reading.	Indicates the magnitude of oscillation of V101 by measuring its grid current.	HA-3701
M102	METER, ammeter: thermo r-f, for use with ext thermocouple E102; scale marked 0 to 100 ma; round HS metal case, ±2% accuracy for full-scale reading; calibrated with thermocouple E102.	CRYSTAL CURRENT meter; measures the magnitude of r-f current through the crystal under test.	HA-6662
E112	PLATE, vernier scale.	Vernier scale for load capacitor dial.	HA-3835
E113	PLATE, vernier scale.	Vernier scale for tuning capacitor dial.	HA-30986
R101	RESISTOR, fixed: carbon-film; 1 ohm ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-589
R102	RESISTOR, fixed: carbon-film; 2 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-590
R103	RESISTOR, fixed: carbon-film; 3 ohms ±1%, 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-591
R104	RESISTOR, fixed: carbon-film; 4 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-592
R105	RESISTOR, fixed: carbon-film; 5 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-593
R106	RESISTOR, fixed: carbon-film; 6 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-594
R107	RESISTOR, fixed: carbon-film; 7 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-595
R108	RESISTOR, fixed: carbon-film; 8 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-596
R109	RESISTOR, fixed: carbon-film; 9 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-148
R110	RESISTOR, fixed: carbon-film; 10 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-597
R111	RESISTOR, fixed: carbon-film; 20 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-598
R112	RESISTOR, fixed: carbon-film; 30 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-599

SYMBOL	DESCRIPTION	FUNCTION	RFL PART NO.
R113	RESISTOR, fixed: carbon-film; 40 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-600
R114	RESISTOR, fixed: carbon-film; 50 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-588
R115	RESISTOR, fixed: carbon-film; 60 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-601
R116	RESISTOR, fixed: carbon-film; 70 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-602
R117	RESISTOR, fixed: carbon-film; 80 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-603
R118	RESISTOR, fixed: carbon-film; 90 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-604
R119	RESISTOR, fixed: carbon-film; 100 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-581
R120	RESISTOR, fixed: carbon-film; 200 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-605
R121	RESISTOR, fixed: carbon-film; 300 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-606
R122	RESISTOR, fixed: carbon-film; 400 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-607
R123	RESISTOR, fixed: carbon-film; 500 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-608
R124	RESISTOR, fixed: carbon-film; 600 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-609
R125	RESISTOR, fixed: carbon-film; 700 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-610
R126	RESISTOR, fixed: carbon-film; 800 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-611
R127	RESISTOR, fixed: carbon-film; 900 ohms ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-612
R128	RESISTOR, fixed: carbon-film; 1K ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-613
R129	RESISTOR, fixed: carbon-film; 2K ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-614

SYMBOL	DESCRIPTION	FUNCTION	RFL PART NO.
R130	RESISTOR, fixed: carbon-film; 3K ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-582
R131	RESISTOR, fixed: carbon-film; 4K ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-583
R132	RESISTOR, fixed: carbon-film; 5K ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-584
R133	RESISTOR, fixed: carbon-film; 6K ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-585
R134	RESISTOR, fixed: carbon-film; 7K ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-586
R135	RESISTOR, fixed: carbon-film; 8K ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-587
R136	RESISTOR, fixed: carbon-film; 9K ±1%; 1/2 w.	Calibration resistor; part of decade resistor.	H-1510-615
R137	RESISTOR, fixed: comp; 2200 ohms ±5%; 1 w.	Drops r-f in tuned grid circuit of V101.	H-1009-180
R138	RESISTOR, fixed: Same as R137.	Drops r-f in tuned plate circuit of V101.	
R139	RESISTOR, fixed: comp; 22K ±5%; 1 w.	Grid leak resistor for V101.	H-1009-177
R140	RESISTOR, fixed: comp; 270 ohms ±10%; 1 w.	Cathode bias resistor for V101.	H-1009-181
R141	RESISTOR, variable: comp; 1K ±10%; 3 w.	GRID CURRENT control resistor which adjusts the sensitivity of meter M101.	HA-5373
R143	RESISTOR, fixed: WW; 15K ohms ±5%; 12 w.	Filters output of V102.	H-1100-397
R144	RESISTOR, fixed: Same as R143.	Filters output of V102.	
R145	RESISTOR, fixed: Same as R143.	Filters output of V102 and regulates d-c voltage to plate of V101.	
R142	RESISTOR, variable: comp; 25K ±10%; 3 w.	CRYSTAL CURRENT control resistor; controls magnitude of oscillation by varying the voltage on the screen grid of V101.	HA-5374

SYMBOL	DESCRIPTION	FUNCTION	RFL PART NO.
X101	SOCKET, tube: ceramic insulation.	Socket for V101.	HA-3733
X102	SOCKET, tube: plastic insulation.	Socket for V102.	HA-4787
X103	SOCKET, tube: Same as X102.	Socket for V103.	
X104	SOCKET, tube: Same as X102.	Socket for V104.	
S107	SWITCH, lever: two position, non-locking; DPDT.	CALIBRATE CRYSTAL control; switches either the test crystal or substitution decade resistors into oscillator circuit.	HB-3704
S101	SWITCH, rotary: 4 pole, 10 position; 4 sect.	Selects a substitution resistor.	HB-3707
S102	SWITCH, rotary: 4 pole, 10 position; 4 sect.	Selects a substitution resistor.	HB-3708
S105	SWITCH, rotary: 2 pole, 7 position; 2 sect.	MEGACYCLES switch; changes frequency range by selecting various inductances.	HB-3706
S106	SWITCH, rotary: 1 pole, 9 position.	LOAD CAPACITY control; selects load capacitors; shorts out the load capacitors for series resonance test of crystal units.	HB-8715
S103	SWITCH, toggle: DPDT.	X1-X100 switch; changes resistance decades on switch S101.	HA-3710
S104	SWITCH, toggle: Same as S103.	X10-X1000 switch; changes resistance decades on switch S102.	
S109	SWITCH, toggle: Same as S103.	115/230 volt switch.	
S108	SWITCH, toggle: SPST.	Power switch; controls a-c into the C. I. Meter.	HA-3709
E102	THERMOCOUPLE: p/o Meter M102.	Thermocouple for M102 (CRYSTAL CURRENT meter).	HA-6512
T101	TRANSFORMER, power: filament and plate type; input 115/230 v, 50-1000 cyc, single phase; 3 output windings; secd No. 1 - 700 v CT at 35 ma, secd No. 2 - 5 v at 3 amp, secd No. 3 - 6.3 v at 2.5 amp.	Power supply transformer.	HB-8718

SYMBOL	DESCRIPTION	FUNCTION	RFL PART NO.
V101	TUBE, electron: 6V6GT; beam power amplifier.	Oscillator tube.	HA-2016
V102	TUBE, electron: 5Y3WGTA; full-wave rectifier.	Rectifier tube.	HB-4836
V103	TUBE, electron: OC3/VR105; voltage regulator.	Regulates d-c voltage to plate of V101.	HA-1276
V104	TUBE, electron: Same as V103.	Regulates d-c voltage to plate of V101.	

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